Austral Wright Metals

at the
cutting
edge

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PRODUCT DATA SHEET

Copper-Nickel Alloys

UNS C70600, C71500

Copper Alloys

Excellent Resistance to Corrosion and Bio Fouling in Sea Water

Copper-nickel alloys have high resistance to sea water environments. There are two common alloys, containing nominally 10% and 30% of nickel. The 10% nickel alloy is the most widely used for sea water handling service.

Table 1: Chemical Composition, % (ASTM B466 Seamless copper nickel pipe & tube)

Alloy	Name	Copper	Nickel	Iron	Lead
C70600	**90-10 copper nickel**	~ 89	9.0 – 11.0	1.0 – 1.8	< 0.05
C71500	**70-30 copper nickel**	~ 69	29.0 – 33.0	0.4 – 1.0	< 0.05

There are several variations in composition giving other alloys within the within the cupper nickel series. A small content of iron is essential for best performance.

Sea Water Pipe Work

Copper-nickel is an established pipe work alloy for many of the world’s navies. It is also used in merchant shipping, the power industry and offshore for a variety of purposes.

Offshore Fire Water Systems

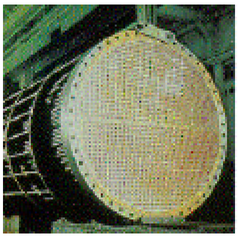
Sea water deluge fire extinguishing systems in copper-nickel have been selected for offshore platforms over many years.

Copper nickel alloy pipework on a natural gas platform in Morecambe Bay, UK.

Photo: British Gas Corporation

This data sheet is adapted from COPPER DEVELOPMENT ASSOCIATION Publication 118 December 1996

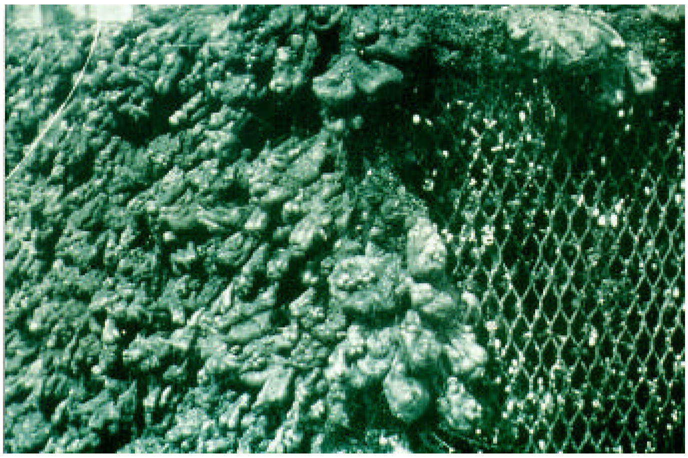
Heat Exchangers and Condensers



Good thermal conductivity and corrosion resistance to the sea water flow rates required have allowed copper-nickel tubing to remain an established alloy where high reliability is called for.

Sea Water Intakes

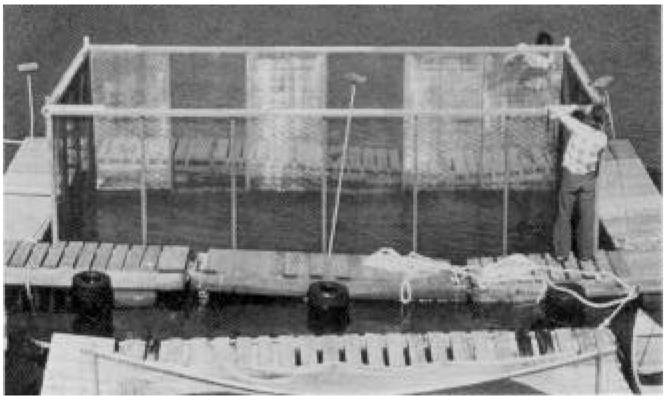
Fouling on intakes and intake screens can restrict water flow and if detached cause blockages to heat exchangers or cause mechanical damage to pumps and valves. Copper-nickel with its high resistance to macrofouling can be very beneficial in this application.



Unfouled copper nickel alloy mesh (right) with adjacent heavily fouled galvanised steel mesh after exposure in sea water.

photo: International Copper Research Association

Fish Farming



The excellent bio-fouling and corrosion resistance of 90/10 copper-nickel mesh coupled with its mechanical strength and low resistance to water flow, make it an ideal material for the large scale development of underwater pens and enclosures. thus adding a new dimension to fish farming.

The biocidal properties of the 90/10 copper-nickel alloy surface help to prevent fouling of fish cages fabricated from woven wire or expanded mesh. There is no extra uptake or accumulation of copper by the fish. They are as palatable as those grown naturally and appear to grow more rapidly than fish reared in cages of other material. Further details of these advantages are found in literature which is available from Austral Wright Metals.

Sheathing of Legs and Risers on Offshore Platforms

Copper-nickel is used for splash zone corrosion protection on oil/gas platform legs and riser pipes either as welded sheet or as a composite with neoprene. In an insulated form it provides antifouling properties too, which reduces wave drag and cleaning operations on the structures. More novel applications include sub-sea markers made from copper-nickel wire gauze which remain fouling free to help divers identify submerged structural areas.

Boat Hulls Copper-nickel is one of the few engineering materials with good inherent resistance to both corrosion and biofouling making the alloy a suitable material for boat hulls without recourse to cathodic protection or antifouling and anticorrosion paints.

Hydraulic Lines With adequate strength to withstand pressures in most marine hydraulic and instrumentation systems, copper-nickel provides good service, combined with ease of manipulation at installation.

Desalination Units Considerable quantities of 90-10 copper-nickel are used in Multi-Stage Flash Desalination Units predominately located in the Middle East. The alloy is a prime condenser tubing material for the Heat Recovery Section and is also used for water boxes, tube plates and other fabrications as solid material or as clad steel plate.

ALLOY PROPERTIES

Low General Corrosion Rates in Sea Water General corrosion rates are normally in the order of 0.0025-0.025mm/yr, which makes the alloy suitable for requirements in most marine applications.

Resistance to Stress Corrosion Cracking Due to Ammonia in Sea Water

Copper based alloys (e.g. brass) can be susceptible to ammoniacal stress corrosion cracking. However copper-nickel has the highest resistance to this and stress corrosion in sea water is not known to be a problem.

High Resistance to Crevice Corrosion & Stress Corrosion due to Chlorides

Copper-nickel is not susceptible to the type of crevice corrosion and stress corrosion cracking found in stainless steels. As such there is not a related temperature limitation for use in chloride environments.

Good Pitting Resistance The resistance to pitting in clean sea water is good and if pits do occur they tend to be broad and shallow in nature rather than undercut.

Readily Weldable and No Post Weld Heat Treatment Required

Copper-nickel is straightforward to weld by conventional welding techniques. The alloy can also be welded to steel.

Easy to Fabricate Hot and cold working techniques can be used but because of the good ductility of the alloy, cold working is normally preferred.

Sea Water Piping Systems can last a Ship's Lifetime Experience over the last 40 years has confirmed the durability of copper-nickel.

Inherent Resistance to Biofouling The protective oxide surface film which forms naturally on CuNi in sea water also provides an inhospitable surface to deter marine growth.

CORROSION IN SEA WATER

The 90/10 and 70/30 cupronickel alloys both have excellent resistance to bio-fouling and corrosion in sea-water with some variations in the performance of the alloys under different conditions as shown in Tables 10 and 11. For example, the 90/10 alloy has better bio-fouling resistance. The corrosion resistance of the 90/10 and 70/30 alloys in heat exchangers and condensers is compared with a number of other alloys in Figure 1. Table 7 gives the relative resistance of various alloys to fouling in quiet sea-water. If water velocity is accelerated above 1 m/sec, any slight bio-fouling on metal with good fouling resistance will be easily detached and swept away. On a material that does not have this good fouling resistance, strongly adherent, marine organisms would continue to thrive and multiply.

DESIGN CONDITIONS FOR SEA WATER SERVICE

The effect of water velocity on fouling and corrosion rates of various metals is shown in Figure 1, which also shows the typical service design speeds for some items of common equipment in contact with sea-water. The excellent corrosion resistance of 70/30 and 90/10 copper nickel alloys and their suitability for many applications can be seen. Some materials with apparently better corrosion resistance may have disadvantages such as lack of resistance to bio-fouling, lack of availability in the forms required, or susceptibility to crevice corrosion. They may also be more expensive and therefore less cost-effective over the required service lifetime.

CREVICE CORROSION AND BIOFOULING

Crevice corrosion can occur in components in sea-water when they are locally starved of oxygen at a joint or under attached bio-fouling. Table 8 shows the good tolerance of the copper-nickel alloys to this type of attack, giving these alloys advantages over other materials of equal corrosion resistance.

The copper-nickel alloys have good corrosion resistance in the quiescent or stagnant conditions which may occur during the commissioning or overhaul of plant. Where plant is not being used at design speeds some other materials may fail.

MECHANISM OF CORROSION RESISTANCE

The corrosion resistance of the alloys is due to the protective surface film formed when in contact with water. On initial immersion cuprous oxide is formed but complex changes occur in sea water which research work is only now beginning to elucidate. At a flow rate of 0.6 m/s the equilibrium corrosion rate is an almost negligible 0.002 mm/year. Normally, design flow rates of up to 3.5 m/s give a satisfactory safety factor for use in pipework systems. This figure makes allowance for the fact that local speeds may be higher at changes of direction, points of divergence, etc. If water velocity is excessive, it can cause vortices leading to impingement attack which can cause premature failure. Where surfaces in contact with water allow smooth flow, as in ships hulls, different design criteria apply.

As mentioned, the fouling resistance is due to the copper ions at the surface, making it inhospitable to most marine organisms in slowly moving water. In static conditions there may be some deposition of chemical salts and biological slimes, possibly leading to some weakly adherent fouling but such residues are easily detached from the metal's corrosion resistant surface, exposing a fresh, biocidally active surface.

DEVELOPMENT OF A CORROSION RESISTANT SURFACE

When first brought into use, care must be taken to allow copper-nickel alloys to form their protective corrosion resistant surface freely. Normally, this protective film will develop in six to eight weeks. Contact with other less noble metals or with cathodic protection systems must be avoided to ensure development of the corrosion resistant surface film and the non-fouling properties.

STRESS CORROSION CRACKING

Copper-nickel alloys do not suffer the stress-corrosion problems associated with some other materials, such as copper zinc alloys (brass) with more than 15% zinc.

Table 2: MINIMUM MECHANICAL PROPERTIES.

ASTM B111 Copper & copper alloy seamless condenser tubes & ferrule stock

* - note yield stress is the stress at 0.5% strain

Temper	Code	0.5% Proof Stress*	Tensile Strength	Elongation
		MPa	MPa	%
Annealed	O61	105	275	(40)
Cold drawn	H55	240	310	(10)

Table 3: PHYSICAL PROPERTIES

Property	Metric Units	Imperial Units
Melting Point (Liquidus)	1150^{0}C	2100^{0}F
Melting Point (Solidus)	1100^{0}C	2010^{0}F
Density	8.94 gm/cm^3 @ 20^{0}C	0.323 lb/in^3 @ 68^{0}F
Specific Gravity	8.94	8.94
Coefficient of Thermal Expansion	17.1 x 10^{-6}/^{0}K (20 - 300^{0}C)	9.5 x 10^{-5}/^{0}F (68 - 572^{0}F)
Thermal Conductivity	40 W/m.^{0}K @ 20^{0}C	23 BTU/ft^3/ft/hr/^{0}F @ 68^{0}F
Thermal Capacity (Specific Heat)	380 J/kg.^{0}K @ 20^{0}C	0.09 BTU/lb/^{0}F @ 68^{0}F
Electrical Resistivity (Annealed)	0.190 microhm.cm @ 20^{0}C	130 ohms (circ mil/ft) @ 68^{0}F
Electrical Conductivity (Annealed)	5.26 microhm^{-1}.cm^{-1} @ 20^{0}C	9.1% IACS
Modulus of Elasticity (tension)	140 GPa @ 20^{0}C	20.0 x 10^6 psi @ 68^{0}F
Modulus of Rigidity (torsion)	52 GPa @ 20^{0}C	7.5 x 10^6 psi @ 68^{0}F

Table 4: FABRICATING PROPERTIES

Cold Working Capacity	Excellent
Hot Working Capacity	Good
Hot Working Temperature	850 - 950^{0}C
Annealing Temperature	700 - 825^{0}C
Stress Relieving Temperature	275 - 400^{0}C
Machinability Rating	20% of free cutting brass (C36000)
Polishing Finish	Excellent

Table 5: JOINING PROPERTIES

Soldering	Excellent
Brazing	Good
Oxy-Acetylene Welding	Not recommended
Gas Shielded Arc Welding (GTAW/TIG, GMAW/MIG)	Excellent
Coated Metal Arc Welding (Manual electrodes)	Good
Resistance Welding	Good

Table 6: ASTM PRODUCT SPECIFICATIONS

	Title
B469	Seamless copper alloy tubes for pressure applications
B466	Seamless copper-nickel pipe and tube
B552	Seamless & welded copper-nickel tubes for water desalting
B543	Welded copper and copper alloy heat exchanger tube
B608	Welded copper alloy pipe
B467	Welded copper nickel pipe
B151	Copper-nickel-zinc alloy (nickel silver) & copper-nickel rod & bar
B111	Copper & copper alloy seamless condenser tubes & ferrule stock
B359	Copper & copper alloy seamless condenser & heat exchanger tubes with integral fins
B395	U bend seamless copper & copper alloy heat exchanger & condenser tubes
B171	Copper alloy plate & sheet for pressure vessels, condensers & heat exchangers
B122	Copper-nickel-tin alloy, copper-nickel-zinc alloy (nickel silver), & copper-nickel plate, sheet, strip, & rolled bar
B171	Copper alloy plate & sheet for pressure vessels, condensers & heat exchangers

Figure 1: CORROSION RATES OF MATERIALS IN FLOWING SEA WATER.

Approximate corrosion rates are given by the figures on the bars in units/hr (micrometres/year, 1,000 micrometres = 1 mm)

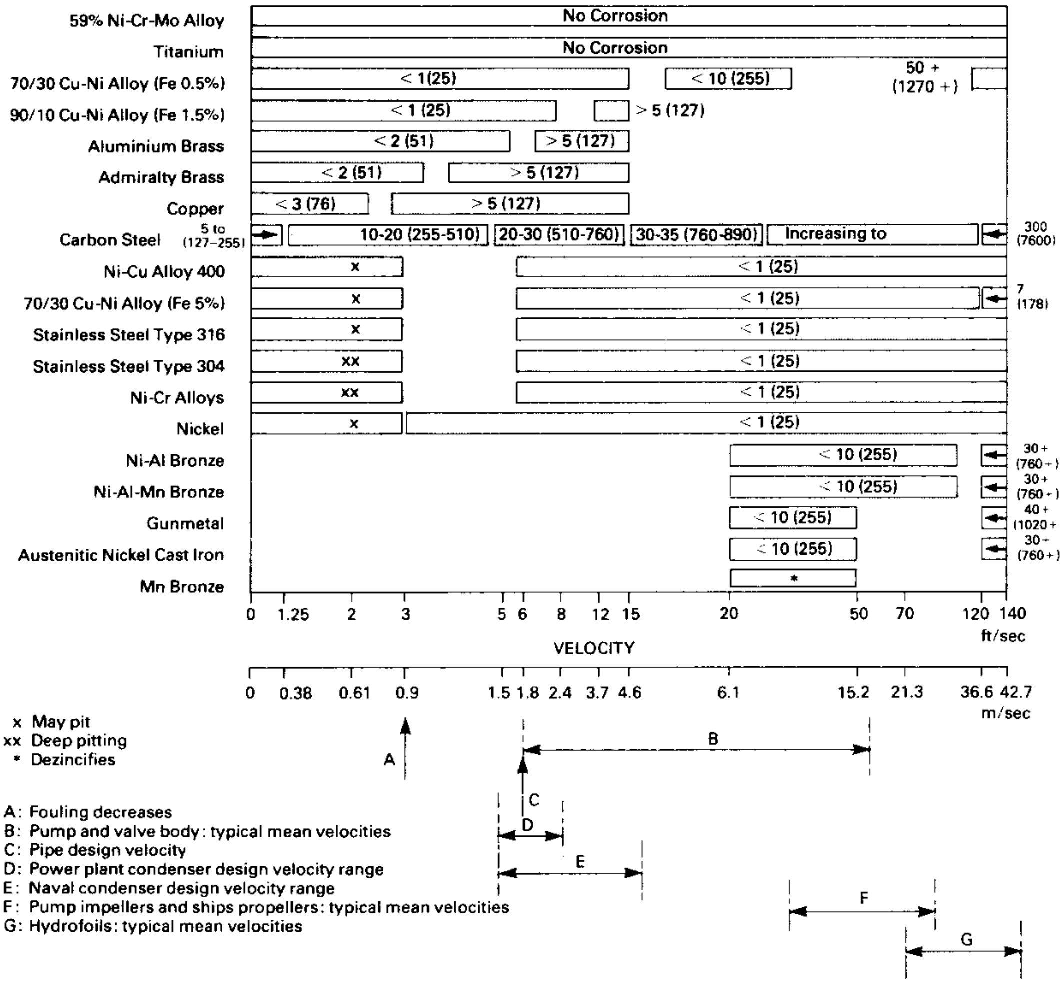


Table 7: FOULING RESISTANCE OF VARIOUS ALLOYS IN QUIET SEA-WATER.

Arbitrary Rating Scale of Fouling Resistance		Materials
90-100	Best	Copper 90/10 copper-nickel alloy
70-90	Good	Brass and bronze
50	Fair	70/30 copper-nickel alloy Aluminium bronzes Zinc
10	Very slight	Monel 400 (nickel-copper alloy)
0	Least	Carbon and low alloy steels Stainless steels Nickel-chromium-molybdenum alloys Titanium

Note: Above 1 m/s (about 3 ft/sec or 1.8 knots) most fouling organisms have increasing difficulty in attaching themselves and clinging to any surface unless already securely attached. (INCO)

Table 8: TOLERANCE FOR CREVICE CORROSION AND PITTING UNDER FOULING IN SEAWATER

Crevices can normally be tolerated in designs using these materials. They may foul but rarely pit.	Titanium Hastelloy C Inconel 625	Titanium will pit at temperatures above 120°C. Inconel 625 after 2-3 years shows signs of incipient pitting in some tests in quiet seawater
	90/10 copper-nickel(1.5 Fe) Admiralty Brass	Shallow to no pitting 90/10 copper-nickel is standard seawater piping alloy.
	70/30 copper-nickel Copper Tin and aluminium bronzes Austenitic nickel cast iron	Good resistance to pitting Useful in piping applications
Useful although cathodic protection required on critical surfaces	Monel 400 (nickel-copper alloy)	Pits tend to be self-limiting in depth at about 1-6 mm. No protection required for heavy sections. Cathodic protection from steel or copper base alloys will prevent pitting on O Ring, valve seats, and similar critical surfaces.
	CN7M (Alloy 20) Incoloy 825	Occasional deep pits will develop. Protection not normally required for all alloy 20 pumps. Cathodic protection from less noble alloys may be necessary for O Ring and similar critical surfaces.
	Grade 316 Stainless Steel	Cathodic protection from zinc, aluminium, or steel is required except when part is frequently removed from seawater and thoroughly cleaned
Crevices cannot be tolerated in designs (But usable in above the waterline marine applications)	Nickel	Many deep pits develop. Cathodic protection from less noble alloys required
	Grade 304 Stainless Steel	Many deep pits develop. Cathodic protection from steel may not be fully effective
	Precipitation Hardening Grades of Stainless Steel	Many deep pits develop. Cathodic protection with zinc or aluminium may induce cracking from hydrogen
Severe crevice corrosion limits usefulness	Grade 303 Stainless Steel	Severe pitting. Cathodic protection may not be effective.
	Series 400 (ferritic or martensitic) Stainless Steel	Severe pitting. Cathodic protection with zinc or aluminium may induce cracking from hydrogen.

DEMONSTRATION OF FOULING RESISTANCE

Panels from 55 week exposure trials conducted at Langstone Harbour, Portsmouth, UK, by IMI Yorkshire Alloys Ltd

Panels are, left to right:

?? carbon steel

?? copper-nickel cladding on steel

?? copper-nickel panels with aluminium anodes

?? freely exposed copper-nickel (far right)

Figure 2: CORROSION POTENTIALS IN SEA WATER

Flowing (2.5 – 4 m/sec) sea water at temperatures in the range 10 – 26°C. The solid bars indicate the potential of stainless steels actively corroding, e.g. in acidic water such as may exist in crevices. The shaded bars for stainless steels indicate behaviour in the presence of a passive film.

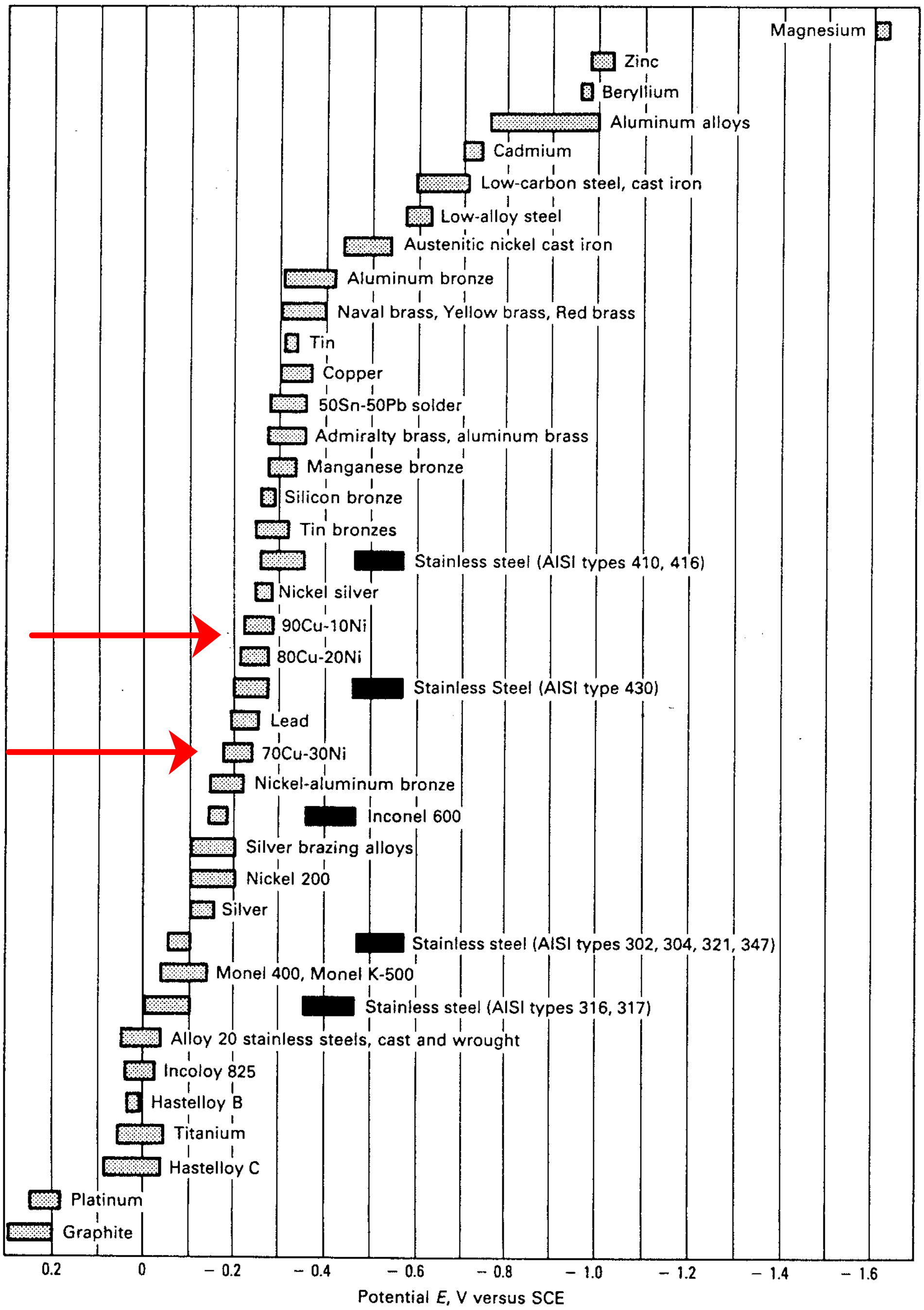


Table 9 Comparison or corrosion behaviour of CuNi10Fe and CuNi30Fe in seawater (in heat exchanger service)

Environmental conditions	**Type of corrosion**	**Service experience**	
		CuNi10Fe	**CuNi30Fe**
Waterside conditions			
Clean seawater at velocities up to 1 m/sec	Uniform, general	0.0025-0.025 mm/yr	0.0025-0.025 mm/yr
Clean seawater at velocities up to 3.5 m/sec*	Impingement attack	Satisfactory	Satisfactory
Polluted seawater	Accelerated general & pitting	Less resistant	Preferred but not immune
Entrained sand in seawater	Accelerated general & erosion	Unsuitable, except in mild conditions	Use CuNi30Fe2Mn2
Accumulated deposits on surface	Local attack	Generally good	Tendency to pit
Hot spots due to local overheating	Local attack by denickelification	Good	Good but some failures in extreme conditions
Corrosion plus stress	Stress corrosion	Very resistant	Very resistant
Vapour side conditions			
Feedwater heaters working under cyclic conditions	Exfoliation attack	Resistant	Susceptible
Non-condensable gases †	Local attack and general thinning	Highly Resistant	Most resistant
Hydrogen sulphide in desalination plant	General attack	Less Resistant	Resistant ‡

* Local velocities caused by obstructions can be very high.
† If concentration of CO_2 is extremely high, stainless steel may be better cholce.
‡ Attack will increase in concentration or temperature.

DESIGN DATA

Allowable design stresses are given in:

AS1210 – 1997, Amendment No 2, September 1998 Pressure Vessels. Maximum metal temperature 300°C for 90/10 copper nickel, 375°C for 70/30 copper nickel.

AS4041 – 1998. Maximum metal temperature 325°C for 90/10 copper nickel, 425°C for 70/30 copper nickel.

Table 10: Corrosion of Copper Nickel Alloys

Medium	90-10 Copper Nickel	70-30 Copper Nickel	Medium	90-10 Copper Nickel	70-30 Copper Nickel
Acetic acid	B	B	Freon	A	A
Acetic anhydride	B	B	Fuel oil	A	A
Acetone	A	A	Hydrocarbons (pure)	A	A
Alcohols	A	A	Hydrochloric acid	C	C
Aluminium chloride	B	B	Hydrofluoric acid	C	B
Aluminium hydroxide	A	A	Hydrogen peroxide	B	B
Aluminium sulphate	B	A	Hydrogen sulphide (dry)	A	A
Ammonia (absolutely dry)	A	A	Hydrogen sulphide (moist)	D	C
Ammonia (moist)	D	C	Magnesium chloride	B	B
Ammonium hydroxide	D	C	Magnesium hydroxide	A	A
Ammonium chloride	D	C	Magnesium sulphate	A	A
Ammonium sulphate	D	C	Methyl chloride (dry)	A	A
Ammonium sulphate	C	B	Nitric acid	D	D
Aniline dyes	C	C	Paraffin	A	A
Barium chloride	B	B	Phosphoric acid	B	B
Barium hydroxide	A	A	Potassium carbonate	A	A
Benzol	A	A	Potassium chloride	A	A
Bleaching powder (wet)	B	B	Potassium dichromate (acid)	D	D
Boric acid	A	A	Potassium hydroxide	A	A
Brines	A	A	Seawater	A	A
Bromine (dry)	A	A	Sewage	A	A
Bromine (moist)	B	B	Silver salts	D	D
Butane	A	A	Sodium bicarbonate	A	A
Calcium bisulphate	B	B	Sodium bisulphate	A	A
Calcium chloride	A	A	Sodium bisulphate	A	A
Calcium hydroxide	A	A	Sodium carbonate	A	A
Carbon dioxide (dry)	A	A	Sodium chloride	A	A
Carbon dioxide (moist)	B	B	Sodium cyanide	D	D
Carbon disulphide	B	B	Sodium dichromate (acid)	D	D
Carbon tetrachloride (dry)	A	A	Sodium hydroxide	A	A
Carbon tetrachloride (moist)	B	A	Sodium hypochlorite	C	B
Chlorine (dry)	A	A	Sodium nitrate	A	A
Chlorine (moist)	C	B	Sodium peroxide	B	B
Chromic acid	D	D	Sodium sulphate	A	A
Citric acid	A	A	Sodium sulphide	C	B
Copper chloride	C	C	Steam	A	A
Copper sulphate	B	B	Sulphur dioxide (dry)	A	A
Crude oil	B	A	Sulphur dioxide (moist)	C	C
Ethers	A	A	Sulphuric acid	B	B
Ethyl acetate	A	A	Sulphurous acid	C	C
Ethyl chloride	B	B	Tannic acid	A	A
Ethylene glycol	A	A	Trichloroethylene (dry)	A	A
Ferric chloride	D	D	Trichloroethylene (moist)	B	A
Ferric sulphate	D	D	Zinc chloride	C	C
Ferrous chloride	B	B	Zinc sulphate	B	B
Ferrous sulphate	B	B			

A = the alloy should be suitable under most conditions of use

B = the alloy has god corrosion resistance

C = the alloy has fair corrosion resistance

D = the alloy is not suitable